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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

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COUNTRY USSR (Leningrad Oblast)

REPORT

SUBJECT Three-Axis Stabilized Platform
for the V-2 Missile

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1. Development of a three-axis stabilized platform for use in a V-2 type missile was conducted at NII 49, Leningrad, from July 1947 to February 1949. The most critical axis (the azimuth axis) included a cylindrical air bearing. The platform was designed for supporting two integrating computers. The first integrator was to be used for course control. Its purpose was to measure the lateral accelerations and to compute correcting signals in order to maintain the missile on its course. The second integrator was used to compute the speed and distance travelled in order to determine the fuel cut-off point. With regard to the stabilized platform, the two integrators were rotated in their housing so as to remain in alignment with the longitudinal axis of the missile. In this manner, the integrators would measure the exact components of the acceleration for which they were designed.

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2. The heart of the stabilized platform was the air bearing gyroscope used for azimuth stabilization. The air bearing gyroscope had been worked on in Germany in the Kreiselgeraete during World War II [see photographs, pages 21-27, and descriptions of these photos on pages 9-11]. (It resulted from the German research on fluid bearings.) It was continued in NII 49 for prospective use in the platform of the V-2 type missile. The work was carried out by NUERNBERG. The research consisted largely in determining optimum methods for reducing the vortices due to the air flow. Because of the compressibility of the air, there was a tendency for relatively undamped oscillation to occur when vortices appeared. A technical discussion of the engineering background for the development of the air bearing is contained on pages 3-27. Detailed technical information on the three-axis stabilized platform is presented on pages 28-30.

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APPENDIX A:

Technical Discussion of Air Bearing

ENGINEERING BACKGROUND FOR THE AIR BEARING GYROSCOPE

1. The Kreiselgeraete group developed a special bearing for compasses, directional gyroscopes, and pendulums operating on the principle of liquid and air flow. This principle became the basis for a number of instruments characterized by extremely low friction. For some special uses where the indication must be reliable without monitoring over long periods of time, ordinary ball or point bearings have too much friction to be satisfactory.
2. Some of these instruments made in Germany by the Kreiselgeraete are described below. Of these instruments, only the terrestrial compass was completely developed and delivered. The polar gyroscope was developed, tested on board ships and on turntables in the laboratory, but not delivered. Thus, by the end of World War II, no experience on their life expectancies and durability was available. The north-seeking compass was also tested on board a vessel once and was found unsatisfactory.

INSTRUMENTS WITH FLUID BEARINGSThe Liquid Bearing

3. The liquid bearing is based on forcing a liquid between the rotor and its bearing support. Liquid is spread over the load bearing surfaces in such a manner as to preclude any solid contact. In order to accomplish this, it is necessary to finish the surfaces of both the rotor and the bearing very accurately. A functional diagram of such a bearing is shown in the first sketch (page 127). A hemispheric object (1) is placed into a similarly shaped bearing (2), having a series of horizontal channels (3) which lead into a chamber for pressurized fluid (5) through small orifices (4). By means of a feed line (6), water is pumped under pressure into the chamber (5). There it enters the channels (3) and space between bearing and the hemisphere (1), where it spreads into a fine film upon which the hemisphere (1) rests with very small clearance. It can then be loaded considerably, without causing appreciable friction. This bearing differs from similar ones in the size of the orifices (4). The size of the channel cross-sections is important to the reduction of fluid consumption and to obtain freedom from vortices which create a higher amount of friction in the bearing.
4. One experiment proved that the friction remained independent of the velocity of the rotor. The coefficient of friction was also found to be independent of the load.
5. Data on an experimental Kreiselgeraete fluid bearing:

a. Sphere diameter:	70 mm.
b. Channel diameter:	3 mm.
c. Orifice diameter:	0.3 mm.
d. Number of orifices per channel:	20
e. Working pressure:	0.3 kg/cm ² over atmospheric pressure
f. Fluid consumption of bearing:	1.5 liters per minute
g. Load carrying capacity of bearing:	4 kg.

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- h. Coefficient of friction: 0.01 cmgr.
- i. Relationship of coefficient of friction to normal ball bearing: 1000/1

The Terrestrial Compass

6. The terrestrial compass is a gyroscope which, independent of magnetic disturbances, aligns itself with the geographic north-south axis. Since the north-south orientation is actuated solely by the rotation of the earth, it is usable in all kinds of weather and visibility conditions. It, however, requires an absolutely immobile base, which restricts its use to non-moving objects.
- Principle of operation [See the second sketch, page 13]: Every gyroscope instrument, when rotated, orientates itself along its axis of rotation, so as to minimize the precessional forces imposed during the rotation. To illustrate, if a gyroscope is mounted in such a manner that its axis of rotation (I) is positioned horizontally and the gyroscope may move about its vertical axis (p), then it will orientate itself in such a manner as to parallel its own axis of rotation to that of the earth and the direction of rotation will correspond then to that of the earth. [See page 13.]
 - Practical Use: Since the moment of rotation which forces the orientation of the (I) axis parallel to the earth's north-south axis is very small, the bearing of the gyroscope along its vertical (p) axis must be as void of friction as possible. Such a bearing may be obtained with a liquid bearing. The design of such a gyroscope compass is shown on page 14.
 - Description of bearing and gyroscope: The rotor (1) is sealed into a sheet metal container (2), and seated by means of two hemispheres (4) in hemispheric bearings (5). A centrifugal pump (6) forces an electrolytic fluid through pipes (7) into pressure chambers (8) and through channels (9) into the space between the hemispheres (4) and the bearing, thus attaining a low friction bearing. The fluid is drawn out of the housing (11) through the section line (7a). In order to decrease the friction further, the current supply of the motor involved in turning the rotor must be furnished without brushes or collector rings. This is accomplished by passing the electric currents through the electrolytic fluid of alcohol and alkaline lye to the rotating contacts of the gyroscope. Silver carbon rings serve as electrodes. (10).

7. Data on the terrestrial compass:

- | | |
|--|------------------------------|
| a. Gyro KA-13 | Inertia equals 150,000 cmgr. |
| b. Input power | 50 watts |
| c. Input power to pump | 20 watts |
| d. Weight of instrument without power supply | 30 kilograms |
| e. Accuracy | 2 degrees |
| f. Run-up time | 25 minutes |

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8. The KA-10 gyro was also used in such a manner, and the accuracy figures were approximately the same. The nomenclature of the gyroscopes is as follows:

- a. KA represents a Kreiselgeraete gyroscope.
- b. 10 represents the size. The figure 10 refers to the diameter of the rotor.

The North-Seeking Master Compass

9. This compass automatically seeks north. Because of the demand for this type of compass, it was developed faster than the others. The Kreiselgeraete firm developed such a compass which was accurate to within plus/minus three degrees. In addition to its north-seeking characteristics, this compass can be used to transmit bearings to slave compasses without the use of amplifiers.
10. In order to clarify the principle involved, a simplification is assumed, whereby the instrument functions on an immobile base and is subject only to the earth's rotational forces. In the fourth sketch [see page 17], vector "U" indicates the north-south direction and the angular velocity of the earth's rotation. On the immobile disc (1), a gyroscope is mounted with its vertical precession axis (3), horizontal sensitivity axis (4), and axis of rotation (5). The (p) axis (3) is relatively free of friction because of a fluid bearing and incorporates a pick-off (6) for precession as well as a torquer (7) to introduce external moments of rotation upon its axis. The precession angle of axis (3) is transmitted by the line (8) through pick-offs (6) to the gyro-setting motor (9), thence to a sensing axis (4). The inclination of axis (4) is measured by means of an accelerometer (pendulum) equipped with sensing points (10) and the values thus obtained are conveyed as electrical potentials, over line (11) to the torquer as well as over line (12) to the gyro-setting motor (13). The motor rotates the base disc (1) in either a right- or left-hand direction, according to the deflection of the pendulum. With gyroscopic compasses, the axis of rotation always aligns itself in the north-south direction. Also shown is a gyro-compass with its axis of rotation oriented east-west, and the sensing axis (4) parallel with the earth's axis. Since the gyro does not take part in the earth's rotation, axis (4) inclines toward the horizon. The pendulum deflects and actuates the torquer (7) and gyro-setting motor (13). The momentum about axis (3) returns axis (4) parallel to the earth, to return to the horizon, and the gyro setting motor is actuated in such a manner as to compel rotation of axis (5) back to a north-south direction. If the rotational moments about axis (4) have positioned it toward the horizon prior to arriving in the north-south direction, then the pendulum will have reached its zero position and does not emit any more pulses until axis (4) leaves the horizon again and causes actuation of the pendulum. The whole system rests only after the axis of rotation returns to the north-south direction. The gyro-setting motor has in this case a two-fold function; one, to support the stabilizing characteristics of the gyroscope and, two, to carry the gyroscope along its axis of the disc (1). This compass is unable to seek north on board a vessel or an aircraft. In order to accomplish this, it is necessary to use another gyro-element for azimuth stabilization and a third gyroscope for stabilization of its axis with axis (4). The gimbal system for such an arrangement is shown on page 17.

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11. The construction of this compass is basically a tri-axial. It is a platform, stabilized horizontally and azimuthally. See accompanying sketch, page 16. The external gimbal (8) is in a bearing within a yoke (10) which supports the whole structure and which by means of axis (9) is rotatable in its azimuth compared to the base plate (12) which is solidly fixed. The stabilizer gyroscopes (2, 3, and 4) are mounted on plate (1), as well as two accelerometers. Gyroscopes (2 and 3) with vertical precession axes stabilize the horizontal stabilizing axes (7 and 8). Gyroscope (4) stabilizes the azimuth axis (9). Plate (1) is controlled by the accelerometers (5) and (6) to keep it horizontal. The electrical connections between the individual components are shown with broken lines. The gyro-setting motor for the azimuth gyroscope (4) is actuated by the pendulum (6). Precession taps (2b, 3b, and 4b) emit directional rotation pulses for the sensitivity axes (7, 8, and 9).
12. This compass was tested once on board a ship and had an average error of plus/minus two degrees. Greater errors were caused by occasional failure of component elements such as pumps, accelerometers, and relays.
13. Data on the north-seeking master compass:
- | | |
|--------------------|--|
| Gyroscope used: | Three KA-13's, one with liquid bearing |
| Accelerometer: | Two liquid bearing accelerometers |
| Power consumption: | Starting: 1000 watts
Running: 400 watts |
| Weight: | 100 kilograms |
| Run-up time: | 30 minutes |
| Accuracy: | 2 degrees |

INSTRUMENTS WITH AIR BEARINGS

14. The development of fluid bearings was continued by the Kreiselgeraete by experimenting with the use of air in the bearings. The air bearing was considered to be an additional step in the development of fluid bearings because of the application of basic principles and of knowledge gained with fluid bearings. There is one important difference between the liquid and air bearings: It was found that the formation of storage spaces must be avoided in the air bearing because that tends to induce an oscillatory condition. The gyro instrument company (Firma Kreiselgeraete) did not utilize the flow but rather the static pressure of the supporting medium in the instruments developed by them, air and fluid bearings. When one stems back the flow of a water faucet that is opened to drip only, but not running freely, then the line pressure is applied to the fingertip as a whole. Now if one slides the finger across, there is a sensation of sliding around on a cushion of water. This phenomenon is applicable for incorporation into construction of a bearing. When the bearing shell is provided with a number of orifices out of which the supporting medium-- such as air -- may seep, after having been relieved of its inherent pressure by restrictive passages in the orifices, then a thin layer remains between bearing shell and bearing journal. Thus, the journal is supported by the fluid. Only after the load factor exceeds a certain value, which is determined by the pressure ahead of the restriction, does the journal contact the bearing shell. The fluid need

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not have any lubricity at all. If, as in this case, it is desirable to achieve the smallest friction possible, as viscous a fluid as possible would be indicated, such as alcohol or water. An especially good inviscid is offered through the utilization of gases, for instance, air. However, the design of an air bearing must take into account the compressibility of air. The actual shaping of the bearing is unhindered in any other way. The bearing journal may be made in the shape of a sphere, hemisphere, cylinder, cone, or any other possible manner.

15. The development of the air bearing at Kreiselgeraete had advanced to a point by the end of World War II where they were used for some production instruments. All the phenomena of the air flow processes were not yet completely understood. The Kreiselgeraete activity was oriented in the direction of lowering the air consumption and of finding a more suitable air compressor of smaller dimensions and lower power demand. At that time, the thinking at Kreiselgeraete was that the air bearing would not supplant the liquid bearing, but would be advantageous for certain special uses.

Construction of a Cylindrical Air Bearing for Accelerometers

16. An air bearing accelerometer is illustrated herein ³/see page 18/. The sensitive element is, in this case, a cylinder (1) around whose circumference an air cushion is maintained. The cylinder slides out of the cylindrical bearing (2) in accordance with the angle of declination. The air cushion is maintained by a stream of air from an air compressor and enters through ports (3), distribution channels (6), and air chambers (5) whence it passes via passage (4), through individual channels (6) which are located around the circumference. It then enters the bearing clearance area through narrow throat jets (7). Special collecting grooves (8) are utilized for the evacuation of the air. It is important that the narrow throated jets be positioned as closely as possible to the bearing surfaces in order to avoid creation of pockets of air. These air pockets through their compressibility tend to induce vibration of the sensitive element.

The Polar Gyroscope

17. Air bearing gyroscopes were investigated by Kreiselgeraete for use as high-latitude instruments. They were constructed in two types. One of those was tested on board a ship, and the other (with cylindrical bearing) was tested in the laboratory only.
18. The construction of a polar gyroscope with cylindrical bearing is as follows ³/see sketch, page 19/: Gyroscopes (1) is solidly built into cylinder (2), which rotates without friction around the horizontal precession axis (3) on the air cushion (4) of the bearing. Cylinder (2) is inclosed by bearing cylinder (5), in which two rows of channels (6) present openings between the air chamber (7) and bearing clearance (4). On bearing cylinder (5), pivots (6) and (9) are attached as sensitivity axes. Pivot (9) is hemispheric in shape and rests on an air cushion, carrying the full load of the rotor rotating around the sensitivity axis. Pivot (8) is centered by a ball bearing. Vertical to precession axis (3), air is carried off through a hollow tube (10), which strikes a baffle (10a), solidly mounted on bearing cylinder (5), creating a support moment around the sensitivity axis during precession. Air for this support is led from bearing clearance (4).

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through the hollow precession axis end (3) into tube (10). Air supply is routed over the intake connection (11) into chamber (12) and moves from there by means of channels (13) into the bearing clearance of hemisphere (14) into free space, whereas the air of the cylindrical bearing clearance leaves between the front side (2a) of the cylinder (2), and the cover lid (5a). The current for the gyroscope is fed by slip wires onto slip rings (17) of pivot (8) and passes through wiring fixed to cylinder (5), to the springs (19), where they pass the current by dot-shaped contacts to the precession axis of the gyroscope. In order to avoid any frictional moments, contact points (19) must lie in the exact center of the axis. The sketch on page 19 is a copy of a drawing furnished by the source. The technical discussion does not contain references to all the points enumerated on this diagram.

19. Data on the polar gyroscope:

- a. Gyroscope used: KA-7 Inertia equals 12,000 centimeter gram second
- b. Air supply: 50 liters per minute at 1.5 atmospheres
- c. Random error: One to two degrees per hour

The Miniature Compass

20. In small vehicles, especially small submarines, the Anschutz compass was supposed to have been replaced by an instrument which was to be smaller and lighter, which would need less power for its operation. In view of the moderate demand on accuracy (plus - minus three degrees), the actuating time should have amounted to only 30 minutes. In solving this problem, the elevation of the axis of rotation is measured by an accelerometer (pendulum). The rotational moments, necessary for the orientation of the gyro towards north, are controlled by the deviation of the accelerometer (pendulum) through electrical impulses on the gyro. This is contrary to the Anschutz compass, which executed measurements of deviation and torque generation through the center of gravity. Although this principle permits utilization of spherical and, thus, universal bearing support, lack of time forced the utilization (as with the polar compass) of a bi-axial bearing, which has a "rolling" error demanding special compensating measures. Developmental work progressed to such an extent that laboratory tests proved the correctness of the principle. It is pointed out that the endeavor to alleviate the effects of air vortex phenomena had not succeeded fully, and that the electrical control installation was not completely engineered.

21. The construction of the gyro with its air bearing for horizontal and vertical axes as well as the power connections for the precession axis is similar to the polar-gyro illustrated on page 19. Another sketch see page 20 shows a simple horizontal cylinder (1) with air bearing, at whose pivot (2) a pendulum has been attached. The pendulum has a capacitive pickoff. A servomotor was provided to process the gyro around its cylindrical axis. Rotor (4) is mounted in pivot (5) and stator (6) is fixed to the external cylinder (7).

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22. Since the compass must be free of friction around all its axes, the pivot (9) of the y-axis was seated in air bearings (10 and 11). The power is fed inductively by three coils rotatable with pivot (9). Only one is shown (as 12). This coil moves as a secondary coil within an iron core (13) with primary coil (14). Since coil (12) within its iron core has a limited travel, the complete transformer must follow the movements of the y-axis.
23. For the purpose of damping the vibrations around azimuth axis (9), a rotational (19) field system is utilized. This creates a braking moment in the copper disc (20). The excitation of the rotational field system (19) is controlled by the capacitive pickoff of pendulum (3) through amplifier (20). Amplifier (20a) feeds a motor (21) to actuate a induction regulator (22), which feeds alternating voltages to the torque generator (6). The torque generator exerts a torque around rotational axis (5) of cylinder (1). (22) also functions as an integrator and smooths out transient torque signals. Its time constant is approximately one minute.
24. When the rotational axis (1a) of the gyro points toward north, the earth's rotation has no influence on the instrument. Should it deviate from the northerly direction, it becomes subject to a component of the earth's rotation and either elevates or de-elevates the northern point from the horizon, whereupon pendulum (3) then reacts with a corresponding deflection to exert a torque around the axis of cylinder (1) so that the cylinder part rotating around the y-axis attempts to orientate itself towards north. This orientation process is oscillatory and is damped by (19) and (20).
25. Data on the miniature compass:
- a. Gyro: KA-7 (I-12000 centimeter gram second)
 - b. Run-in time: About 30 to 35 minutes
 - c. Vibration period, time span, of: 20 minutes
 - d. Accuracy of orientation: plus/minus three degrees

PROTOTYPE EQUIPMENT USING AIR BEARINGS

26. The following were used as direct prototypes for the further development of air bearings at NII 49. The photographs shown on pages 21-27 are actual copies of photographs used for background material in the development of air bearings at NII 49.
- a. Hemispherical Water Bearing: The principle in the construction of such a bearing is shown on the first picture Page 21. The hemispheric bearing shell, into which a similarly shaped journal is fitted, has two rows of orifices. Fluid enters under pressure, into the annular chamber (1). The fluid reaches the channels (3) through bored passages (2). The channels (3) are shaped in such a manner as to avoid any residual kinetic energy in the water when ejected from the orifices into the bearing clearance. The third illustration Page 23 shows a bearing made on this principle. The bearing journal (of six centimeters diameter) is positioned adjacent to the bearing shell.

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The orifices of the bearing shell are easily recognized. The second picture [page 22] shows the bearing in operation, water pouring out of the orifices, but without bearing journal. The emerging water, seeping out of the orifices with nominal pressure, is easily recognized. The bearing is in operation at a pressure of 0.3 atmospheres. At such pressure, the bearing is capable of supporting a load of 10 kilograms. The fluid film between bearing journal and bearing shell is approximately 0.03 millimeters thickness. This thins out somewhat during increase of load factor. At a certain load, bearing journal and bearing shell contact each other and great friction sets in. Up to this load, friction is independent of load factor. At a pressure of 0.3 atmospheres the water consumption assumes a rate of two liters per minute.

- b. Hemispherical Air Bearing: The same bearing may also be operated with air as supporting medium. In this case, the pressure of air must not be greater than 0.06 atmospheres as the journal will show a tendency to vibrate because of the compressibility of air. In order to avoid this oscillation, which assumes periodic contact between the bearing journal and bearing shell, egress channeling must be avoided at the bearing shell, otherwise the air columns in these channels will act as springs. The flexibility of the air cushions, in conjunction with the mass of the supported object, constitute an oscillatory system, which is excited by the air streaming toward it. In order to avoid oscillation, the locations of the channels must be arranged in a manner such as that shown [on page 23].
- c. Spherical Bearings: The illustration [page 23] shows an air bearing that is assembled. In this case, the journal is in the shape of a sphere, with a diameter of two centimeters. The upper bearing shell has been disassembled and lies next to the lower shell with the journal. In the right-hand bearing shell, the two circular rows of egress orifices for air can well be recognized. The spherical journal can be seen in the other bearing half. The sphere has an annular groove machined into it, which is equipped with an egress orifice, permitting the air to pass out through the sphere and axis. This exit is necessary to avoid packing air between the bearing shell and the bearing journal, which would reduce the load bearing factor of the bearing considerably. Egress orifices along side of the bearing axis do not suffice in this case. This air bearing, at a pressure of 0.5 atmospheres, can support an axial load of 150 grams; radially, it can support 140 grams. At such loading the air consumption is 15 liters per minute, based on atmospheric pressure. The fourth illustration [page 24] shows the support for an axis with air bearing.

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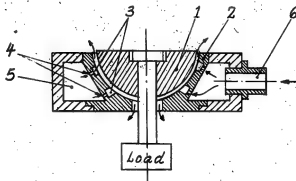
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- d. Cylindrical Bearings: Cylindrical bearings are shown on the fifth, sixth, and seventh pictures page 25 - 27. This arrangement may be utilized as a very sensitive clinometer, somewhat like a water level. A declination of the x-axis for a few arc-seconds causes the cylinder to slide out of the bearing.

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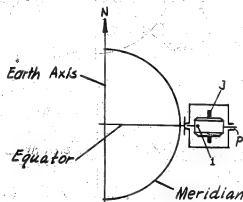
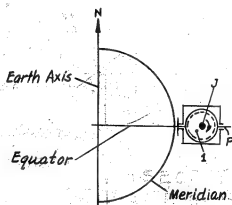


LIQUID BEARING

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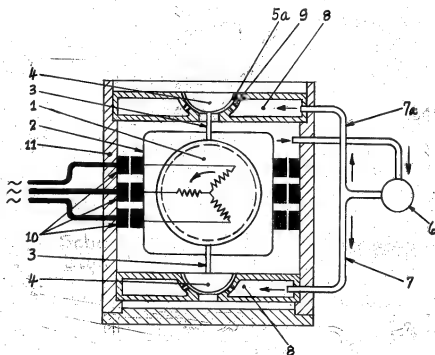
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Principle of Operation of the
North-Seeking Gyroscope

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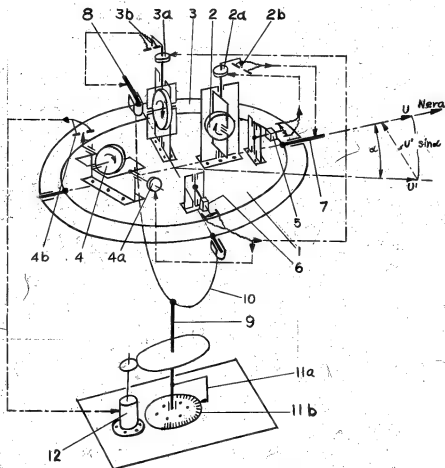
Schematic Diagram of the
Liquid Bearing Compass

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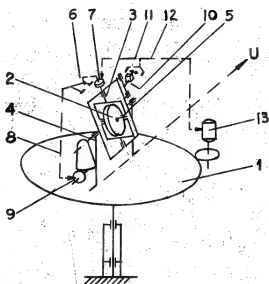
SCHEMATIC DIAGRAM OF NORTH-SEEKING
MASTER COMPASS

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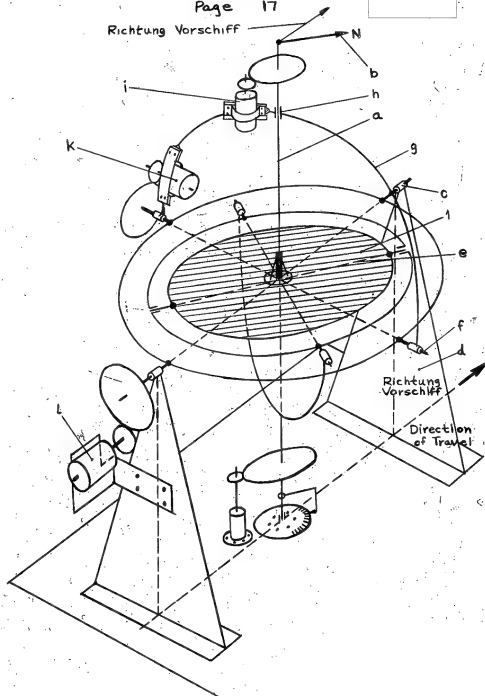
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**GYRO NORTH-SEEKING MASTER COMPASS****SECRET**

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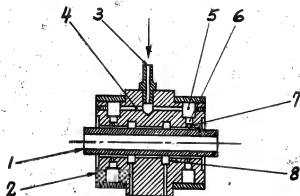
GIMBAL SYSTEM FOR NORTH-SEEKING MASTER COMPASS

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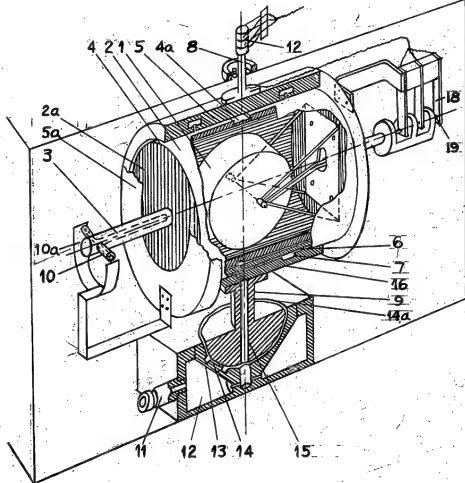


Cylindrical Air Bearing

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Page 19



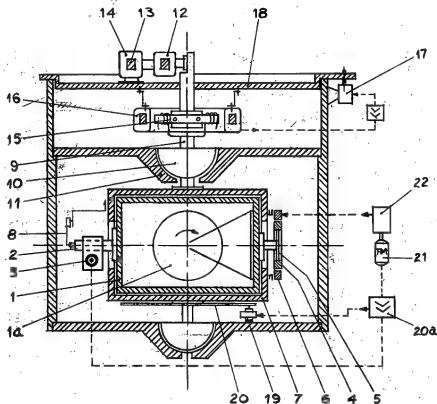
POLAR GYROSCOPE WITH CYLINDRICAL
AIR BEARING

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MINIATURE COMPASS

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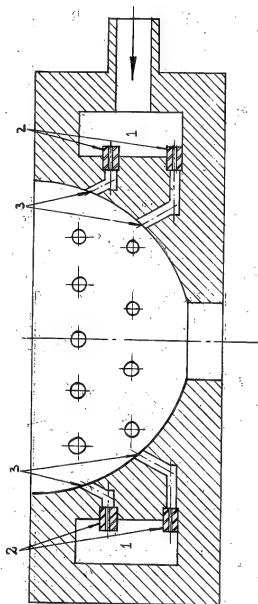


Illustration 1

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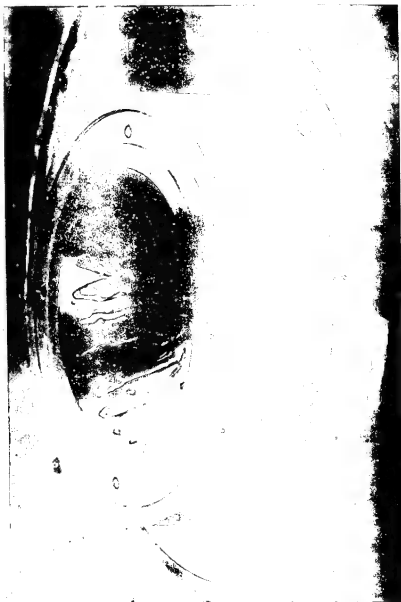
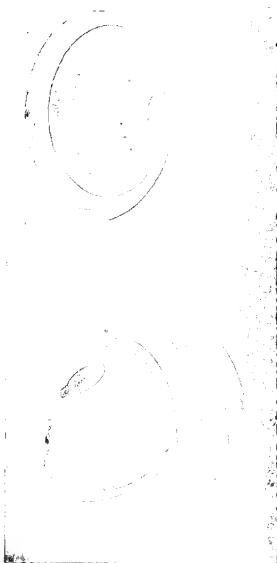


Illustration 2

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Illustration

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Illustration 4

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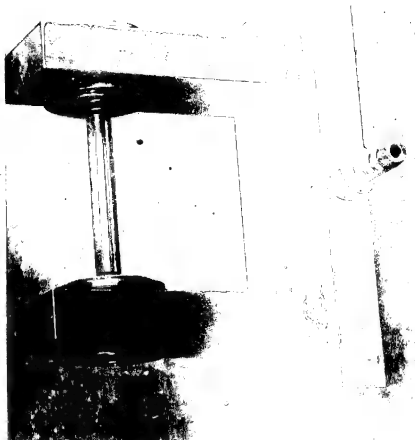


Illustration 5

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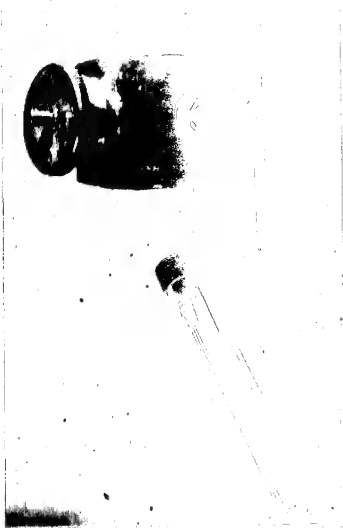


Illustration C

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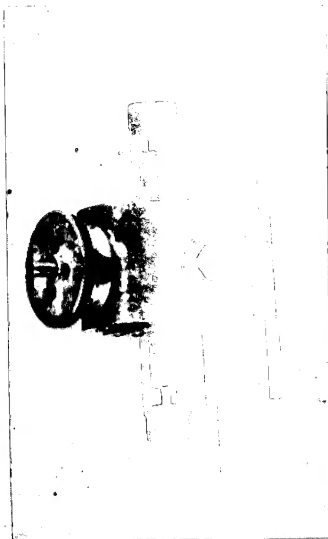


Illustration 7

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APPENDIX B: The Three-axis Stabilized Platform

1. The three-axis stabilized platform consists of three gyroscopes arranged with their axes at 90 degrees to each other. These gyroscopes are mounted on a platform that contains the two integrators used to correct the course and to determine the fuel cut-off point. The platform is mounted on a two-gimbal system which is mounted on the frame of the missile. (Reference is made to the accompanying sketch see page 30 7.) The platform is kept horizontal by sensing vertical through penduli. The reactions of the penduli apply torques to the E and D gyros in their precession axes. The resultant torque, 90 degrees to the precession axes applies moments to right the platform.

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2. The principle involved in the short-term stabilization of the platform is as follows: Twisting or tilting of the missile around the platform tends to leave the platform in its horizontal position. However, due to the frictional forces involved in the bearing of the gimbals and the platform, some precession results. This precession is measured and corrections are applied to the gyroscopes through the erection motors, which apply torques to restore the gyro rotors to their initial positions. comment: there is very little friction in the gimbal and platform bearings, it is believed that the basis for accurate measurement of angular deflection of the missile is through the precession of the gyro rotors themselves. Thus, in effect, the gyroscope system becomes a rate sensitive stabilization system. With this in mind then, the system can be considered as a three-axis rate gyroscope system, whose platform is maintained horizontal through the use of penduli. In this manner, the frictional forces encountered in the gimbal system are of no importance since any friction that appears is reflected in precession of the pertinent gyroscope, and the platform is rotated to cancel out this precession.

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3. The relationship of the precession and sensitivity axes of the three gyroscopes with the missile is shown in the upper portion of the sketch see page 30 7. In the center portion of this sketch is shown an illustration of the mechanical construction of the platform. The azimuthal gyroscope (A-gyro) is mounted on an air bearing similar to that described previously. The air inlet is at the bottom of the drum housing, and the outlets for the air are located at either end of the precession axis. Precession is measured through contacts which permit proportional control of the erection motor A. These contacts are shown in greater detail in the electrical schematic located at the bottom of the sketch. This pickoff is similar to the Silverstat type of gyroscope pickoff. The voltage from the Silverstat type of pickoff operates a split-field DC motor to turn the platform to an angle equivalent to the twist of the missile. A KA-7 gyroscope is used in the A-gyro system. This gyroscope uses a rotor which is seven centimeters in diameter. The speed of rotation is approximately 30,000 rpm and it weighs 1.9 kilograms.

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4. The E-gyro is used to detect turning in the E-axis of the missile. A rate of turn about the E-axis will cause a precession of the E-gyro. This is measured by the contacts located at the top of the gyro mounting, and the E-motor is operated. The E-motor applies a moment about the E-axis, so as to restore the gyroscope rotor to its original position. If the platform rotates about the E-axis, this is detected by the E-pendulum and a torquer mechanically connected to the gyroscope in the precession axis is operated. The torquer applies a moment which restores the platform to a horizontal position. The D-gyro operates in exactly the same manner in the D-axis. Standard KA-10 (Kreiselgeraete) gyroscopes are used for the E- and D-gyro systems.
5. The supply to the windings of the gyroscope drive motors is fed through point contacts aligned axially with the precession axis so as to reduce to a minimum the friction of these contacts. The erection pickoff contacts of the D- and E-gyro systems are not as elaborate as for the A-gyro, in view of the closed loop 50X1-HUM pendulum-controlled erection.

6. [redacted] the Soviets were extremely interested in the platform. [redacted] stabilized platforms were being built in the Soviet sections or NII 49, because of the continual questioning on methods of improvement. [redacted] the Soviets at one time stated that they had built an experimental model, but that the wander rate was as high as two degrees an hour for the air bearing gyroscope. This was evidently because of uneven flow and vortices in the air supply system. [redacted]

After the experimental model made in the German section of NII 49 was turned over at the end of 1950, there still was continual questioning by the Soviets about the design of the platform.

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